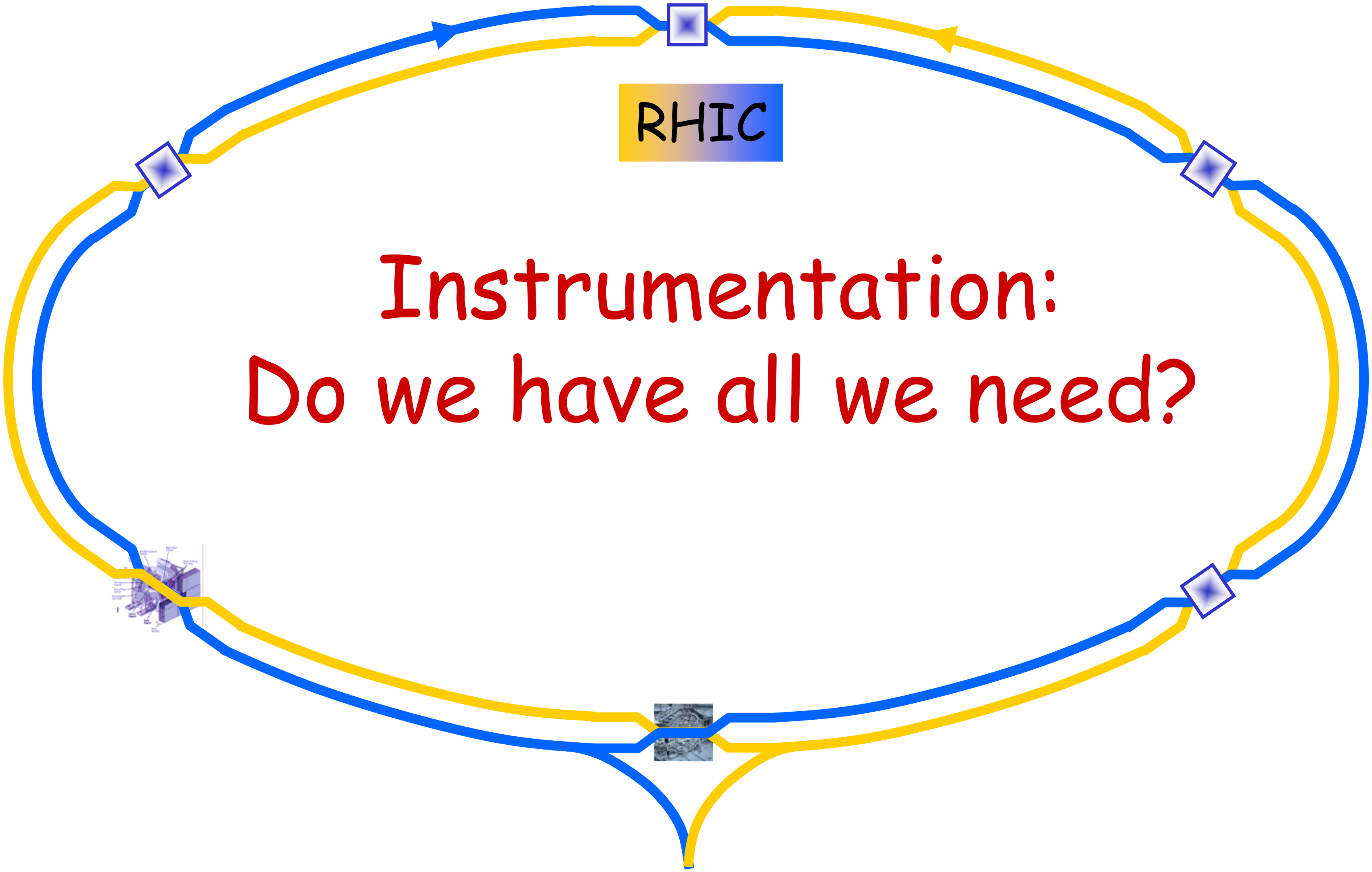


Instrumentation: Do we have all we need?

Vladimir N. Litvinenko

BROOKHAVEN NATIONAL LABORATORY

RHIC

Thanks

- Michael Blaskiewicz, Mike Brennan, Peter Cameron, Wolfram Fischer, Haixin Huang, Yun Luo, Fulvia Pilat, Todd Satogata for the information and for many suggestions

Content

- Conclusions
- AP wish lists
- Beam Instrumentation
  - What to measure
  - How Accurate
- New Instruments - A Short Menu

Conclusions -> NO

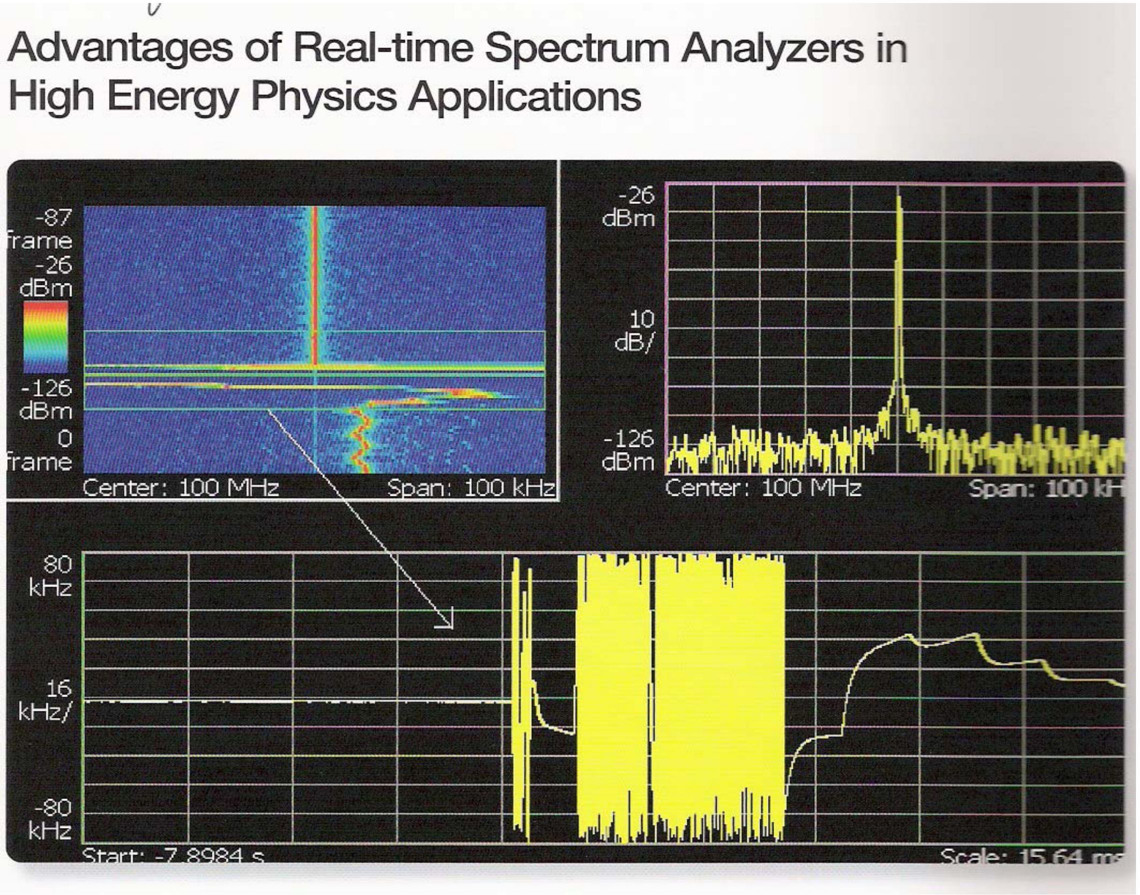
- I.e. there is no requests to remove existing instruments BUT to improve them and/or add new
- Main request - make most of the existing instruments making them more accurate, more (or almost!) reliable and as parasitic as possible
- BPMs
  - Robust 1,000,000 turn BPMs
  - Turn-by-turn, bunch-by-bunch BPMs
  - Reliable, reproducible, stable operation of BPMs -> Bob's talk
- As parasitic As possible, Reliable emittance (profile) measurements for both Ion and Proton beams
  - Improve IPM, Improve HF Schottky -> Peter's talk
  - Assess LF Schottky potential
  - Add wire scanner (flying wire) for protons in RHIC
  - Add visible profile monitor (jet ? u-wiggler?)

Conclusions - cont…

- Reliable & simple chromaticity measurements on the ramp (Schottky)
- Improve reliability of CNI polarimeter -> 2 talks
- Independent real-time measurement of transverse 2D beam profiles
- New instruments requests:
  - Wire scanner
  - Jet (sheet) for 2D beam profile system
  - Real-time Spectrum Analyzer for analyzing instabilities
  - Oscilloscope, with 20 GHz analog bandwidth and a 40 GHz sampling rate for stochastic cooling
  - A couple of low frequency spectrum analyzers for BBQ & 1,000,000 turn BPM

Real Time Spectrum Analyzer

tunes, chromaticity, instabilities, monitoring beam ramping



RHIC: Instrumentation

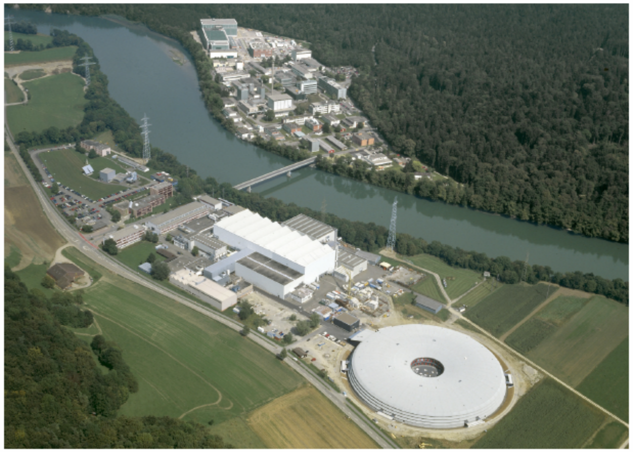
Position monitors	52 measurement planes in transfer line
	667 planes total in collider rings
Ionization profile monitors	One horizontal and one vertical per ring
Wall current monitors	One per ring
Transverse feedback	Two kicker units per ring
	(each provides horizontal and vertical deflection)
Schottky cavities	One per ring
	(each provides horizontal, vertical and longitudinal signals)
Transfer line beam profile monitors	12 phosphor screens mixed into 4 video channels
Transfer line intensity monitors	Five integrating current transformers
Loss monitors	120 ion chambers in the transfer line
	400 ion chambers in the collider tunnel
Collider ring current monitor	One DCCT per ring

And many more…..

Hit List

- Beam Position Monitors
- Emittance measurements
- Schottky
- Polarimeter
- Others

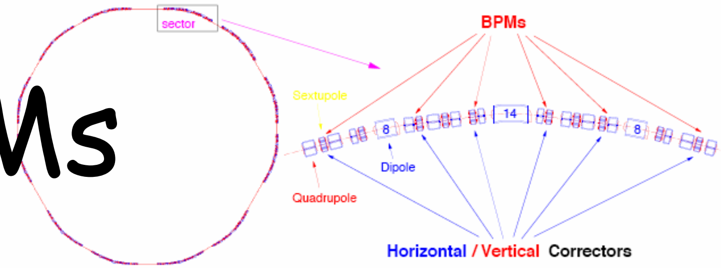
SLS at the Paul Scherrer Institute (PSI), Villigen, Switzerland



Alignment Tolerances and Stability at the SLS

SR - BPM/Corrector Layout

BPMs



- 12 sectors
- 6 BPMs and 6 Horizontal/Vertical Correctors per sector
- Correctors in Sextupoles, BPMs adjacent to Quadrupoles

ERL2005

Alignment Tolerances and Stability at the SLS

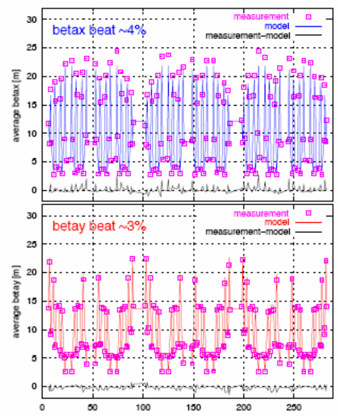
SR - Lattice Calibration - Beta Functions

174 Quadrupoles with Individual PS

$\rightarrow\rightarrow$

Gradient Correction:

- Procedure:
  1. Measure $<\beta_i>$ for i=1..174
     $\delta\nu = -\frac{1}{4\pi}\oint\beta(s)\delta k(s)ds$
     Precision: $\approx$ 1.5 / 1.0 %
  2. Fit Errors δk_i to $<\beta_i>$ (SVD)
  3. Correct $<\beta_i>$ with -δk_i
  4. Measure $<\beta_i>$ again
- Results:
  - Horizontal β Beat: $\approx$ 4 %
  - Vertical β Beat: $\approx$ 3 %



Alignment Tolerances and Stability at the SLS

SR - Stability - Requirements

- β_x = 1.4 m, β_y = 0.9 m at **ID** position of section n**S** $\rightarrow$
  σ_x = 84 μm, σ_y = 7 μm assuming emittance coupling ϵ_y/ϵ_x = 1 %
- With stability requirement $\Delta\sigma = 0.1\times\sigma\rightarrow$

Requirement: Orbit jitter < 1 μm at insertion devices

Noise Scenario from 1998 before SLS construction

	Worst case Noise estimate	30	60	Hz
	Seismic measurements	300	30	nm
	Damping by hall's concrete slab	neglected		
	Girder resonance max amplification	< 10	< 10	
	Closed orbit amplification hor./vert.	8/5	25/5	
→	Maximum Orbit jitter hor./vert	24/15	7.5/1.5	μm
	Attenuation by orbit feedback	−55	−35	dB
→	**Maximum Orbit jitter hor. /vert.**	**40/30**	**130/30**	**nm**

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Vladimir Litvinenko, June 16, 2002, RHIC retreat

RHIC

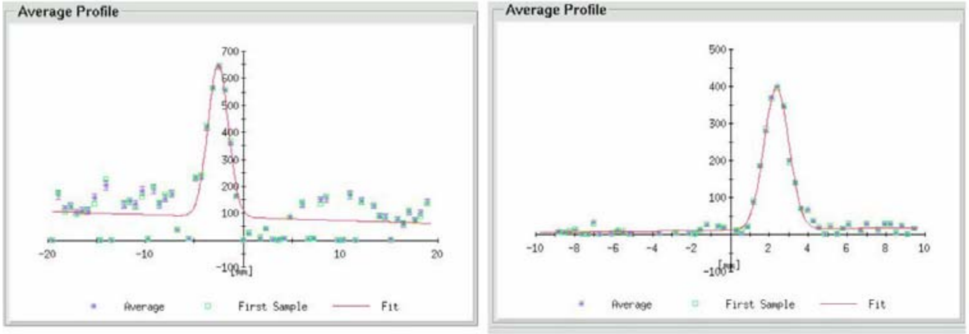
Wish List

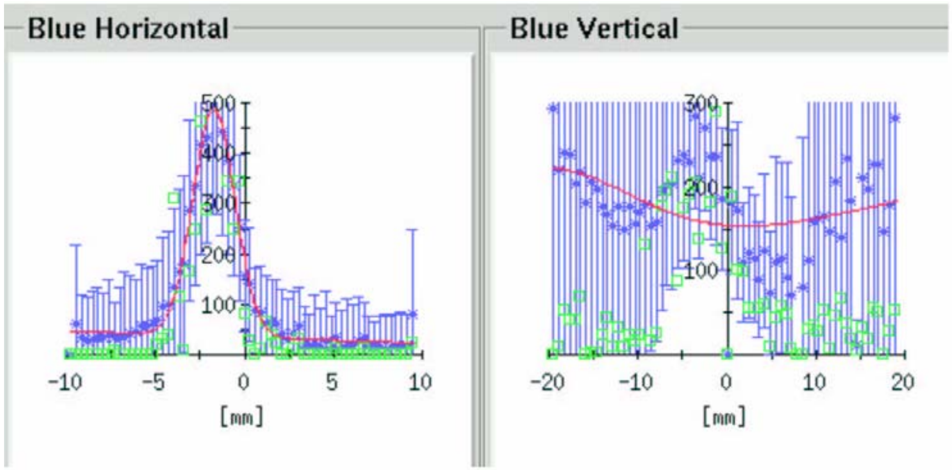
- The Beam & The Lattice
  - Beam parameters: number of bunches, current, losses, IBS, scattering, life-time….
  - Bunch parameters: intensity, polarization (p), real-time 6D phase space distribution for each bunch <-> profiles, emittances, energy spread, bunch-length, …
  - Global parameters of machine: 3 tunes, chromaticities, non-linear tune spread, coupling, dynamic aperture…
  - Local parameters: orbit, β-functions, D-function, eigen modes (i.e. local coupling)…..

RHIC Instrumentation

Ionization profile monitors

One horizontal and one vertical per ring

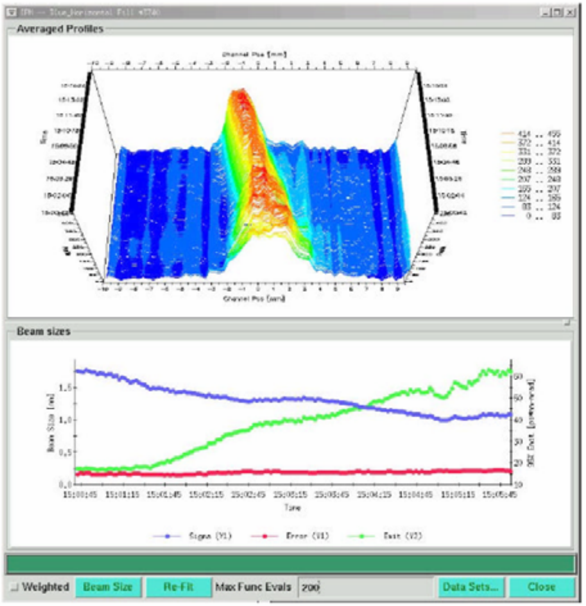




New Detector Design

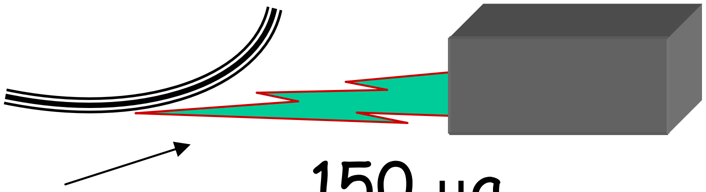
Old Detector Design

Profile of polarized proton beam up acceleration ramp



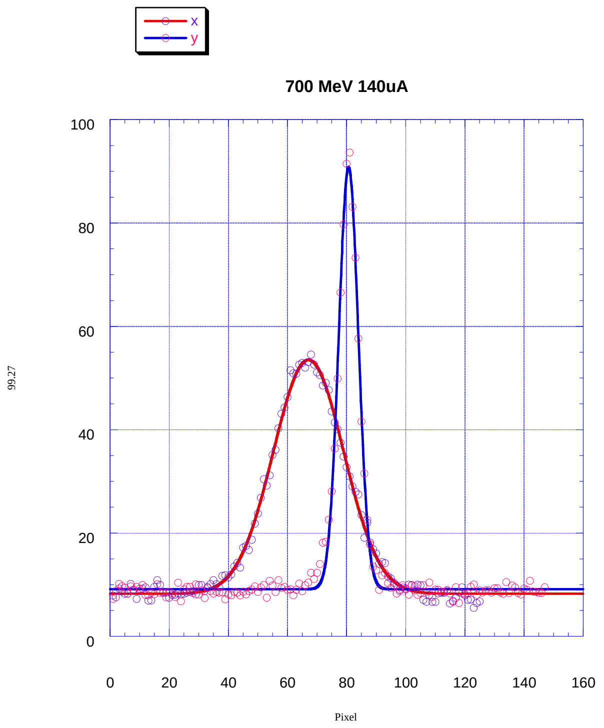
Visible Light Profile Monitors

Give 2-D distribution in real time

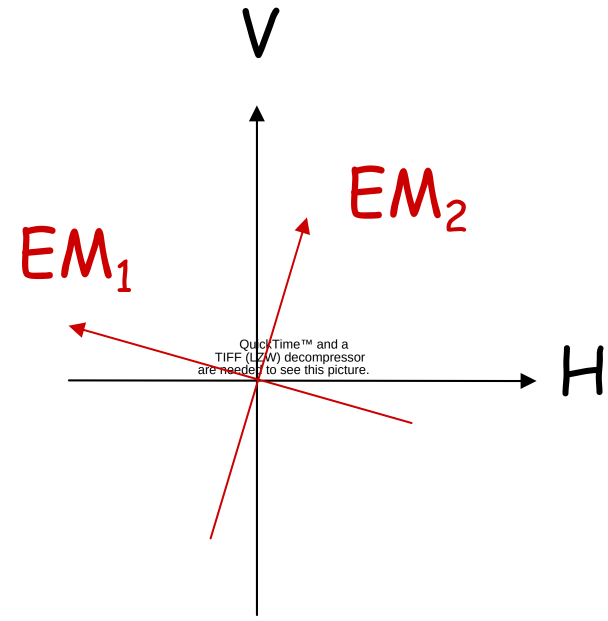


150 μa

8.2 ma



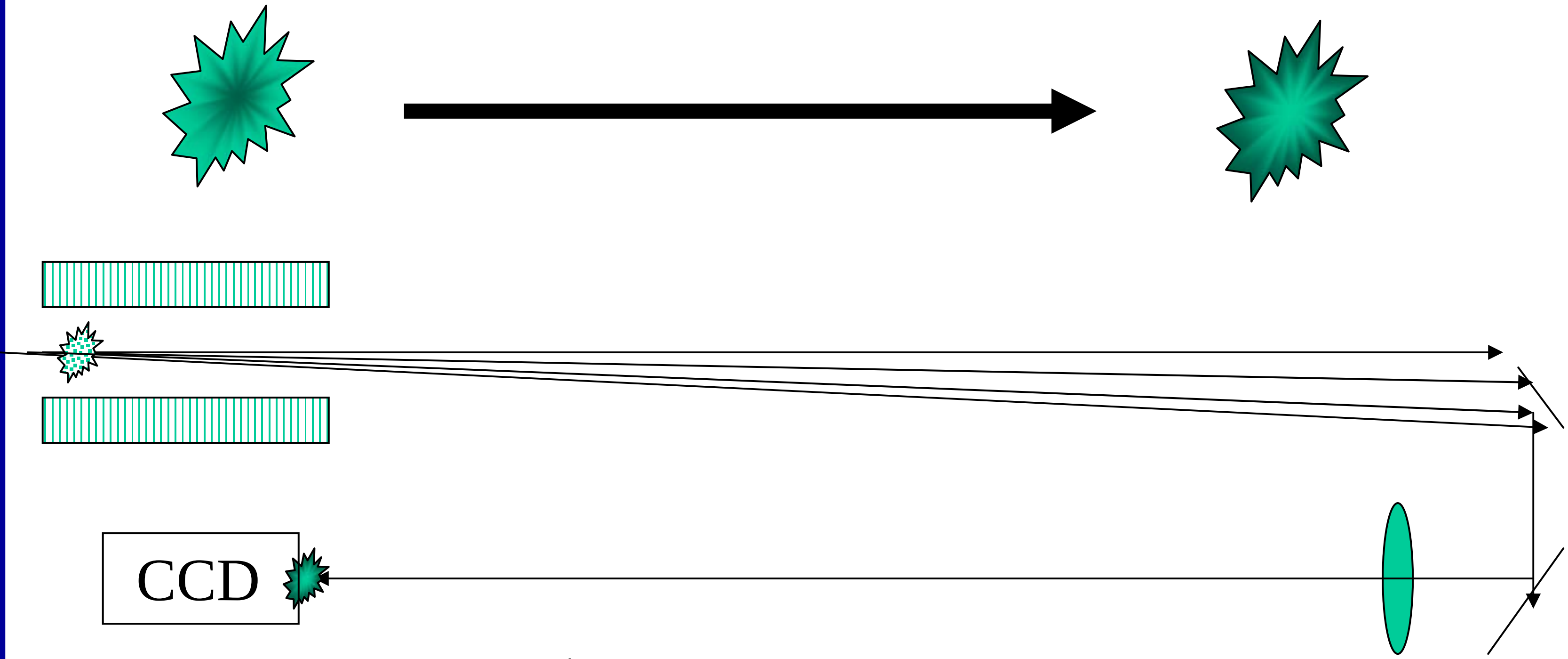
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.



QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

250 μm

μ-wiggler



$$\lambda_{opt} = \frac{1}{2\gamma^2}\lambda_w\left(1+\gamma^2\theta^2+a_w{}^2 \underset{0}{\downarrow}\right)$$

$$\lambda_w = 10mm;\ \ \gamma = 107 \quad \Rightarrow \lambda_{opt} \sim 500nm$$

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RHIC

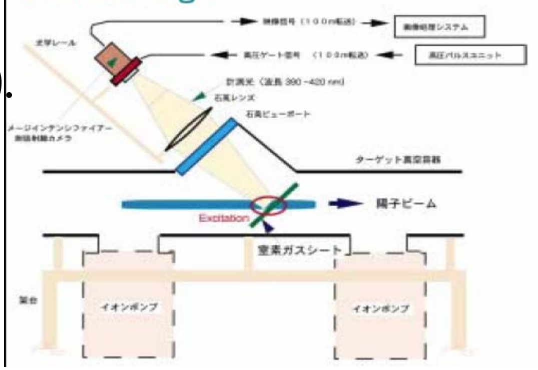
Problems with μ-wiggler

- Flux is rather low for ions
  - Lower flux for protons vs ions with given γ
- Works only at high energies (>100 GeV/u)
- Non-uniform
- Will be easier for 250 GeV protons !!!

Beam Profile Monitor

Sheet–beam

basic design



J-PARC (Japan Proton Accelerator Research Complex).

- ✓ Non-destructive
- ✓ Fast Measurement
- ✓ 2- dimensional Profile

Gas density	5×10^{-6} [Torr]
Gas sheet size	$100^{W} \times 250^{L} \times 1^{T}$ [mm]
Target uniformity	$< \pm 3$ %
Gas species	N_2 (candidate)
Measurement Cycles	30 [times/sec]
Measurement Time	< several bunches
Vacuum contamination in the ring	< 1 x10-8 [Torr]
Wave length of luminescence light	390 [nm] (N_2)
Fast gated camera	HARP camera +image intensifier

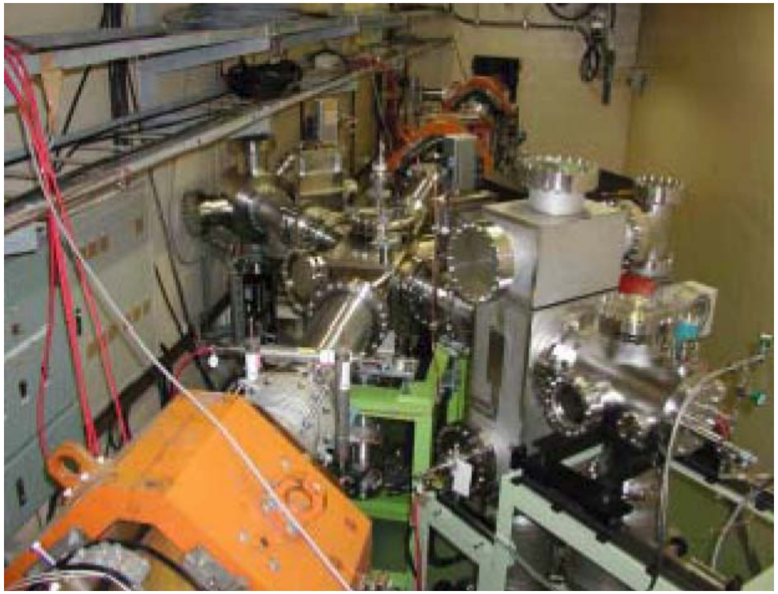
Beam Profile Monitor

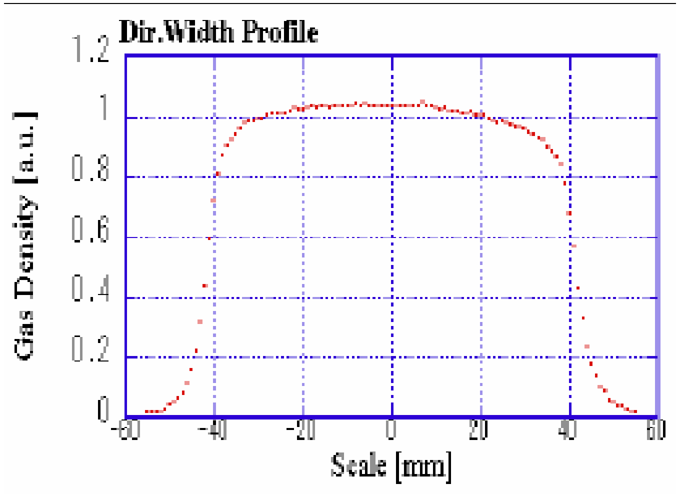
R&D with the 500 MeV beam of the KEK-PS

Gas generator

Differential Pumping (3 stages)

Short N_2 Pulse (~200 μsec)





-> Dejan's talk on Jet camera

Example of performance matrix (P.Cameron)

Functions: tune, chromaticity, and coupling

- Artus
- 245MHz PLL
- Baseband PLL (BBQ)
- LF Schottky
- HF Schottky
- TW Schottky
- others (3D for head-tail chrom, BBA,,,)

Example, cont.

Things you want to measure

- tune - coherent and incoherent
- tune spread
- linear chromaticity
- non-linear chromaticity
- skew chromaticity
- coupling

Machine conditions

- ions at injection
- ions at transition
- ions at store
- protons at injection
- protons on the ramp
- protons at store

Other considerations

- bunch-by-bunch measurements
- instability monitor

Device vs Machine Condition

	ions at inj	p at inj	ramp	hi-res γ_t	ions at store	p at store	comments
Artus	4	4	4	0	1	1	
PLL	4	4	4	1	1	1	
BBQ	5	5	5	5	5	5	but 60Hz!
LFS	4	2	3	2	2	2	PLL excitation!!
HFS	0	4	4	4	4	4	need beam-synchronous LO
TWS	0	3	3	3	3	3	single plane, bunch-by-bunch
3DS	4	4	4	4	4	4	no excitation

Device vs Parameter at Injection

Heavy Ions

	tune	tune sprd	coupl	lin Q'	nl Q'	ε	dp/p	comments
Artus	4	0	4	4	3	0	0	
PLL	4	0	4	4	3	0	0	
BBQ	5	0	5	5	4	0	0	but 60Hz!
LFS	4	3	1	3	2	3	3	killed by 245MHz PLL excitation
HFS	0	0	0	0	0	0	0	η large, lines merge
TWS	0	0	0	0	0	0	0	η large, lines merge
3DS	4	0	3	0	0	0	0	no excitation

Device vs Parameter at Injection
Protons

	tune	tune sprd	coupl	lin Q'	nl Q'	ε	dp/p	comments
Artus	4	0	4	4	3	0	0	
PLL	4	0	4	4	3	0	0	
BBQ	5	0	5	5	4	0	0	but 60Hz!
LFS	2	1	1	2	1	2	2	killed by 245MHz PLL excitation
HFS	4	2	1	3	0	4	4	
TWS	4	2	1	3	0	4	4	
3DS	4	0	3	0	0	0	0	no excitation

Device vs Parameter at Store

beam-beam, 197MHz RF

	tune	tune sprd	coupl	lin Q'	nl Q'	ε	dp/p	comments
Artus	1	0	1	1	1	0	0	killed by beam-beam,...
PLL	1	0	1	1	1	0	0	killed by coherent spectrum
BBQ	5	0	5	5	4	0	0	but 60Hz!
LFS	2	1	2	2	2	2	2	killed by coherent spectrum
HFS	3	1	0	2	0	4	3	hurt by large dp with ions
TWS	3	1	0	2	0	4	3	single plane, bunch-by-bunch
3DS	4	0	3	0	0	0	0	no excitation

Conclusion

NOT (or never?) ENOUGH